3. During the early fall months the upper air winds reported by pilot balloon stations showed normal summer conditions, i. e., variable but mostly southwest at high altitudes over the far Western States.

4. In November the winds over the far Western States up to high altitudes were prevailingly from the north [1] as shown by pilot-balloon runs, whereas normally they would be changeable between southwest and northwest.

5. Over the ocean in November the barometer stood high over and off our western coast to a considerable distance, but over midocean and the Bering Sea it stood low with numerous cyclones forming and moving north or northeastward to the Bering Sea and the Bay of Alaska. No one of these of importance reached the coast of North America south of Vancouver Island.

6. It would appear that the September and October cyclones of the north Pacific Ocean were unable to penetrate the high barometric pressure and its system of winds; instead they moved along the northern periphery of the high pressure area in high latitudes.

7. The high barometric pressure along and off our western coast during November was an effective barrier to the eastward advance of many cyclones that made their appearance over midocean and moved to the Bering Sea where they disappeared beyond our field of observations.

8. The northerly winds prevailing up to high altitudes over the far Western States would account for the scarcity of precipitation in that region during November. This occurrence was associated with the high barometric pressure referred to in 2, and it, no doubt, occurred in response to temperature abnormalities over a large area. It will be recalled that with the trial forecast of the seasonal rainfall for southern California for the winter of 1929–30, issued by the Scripps Institution of Oceanography, the statement was made that the water temperatures off La Jolla, Calif., during the summer of 1929, were the highest recorded since observations began there. If high water temperatures prevailed over a considerable area of the ocean off the western coast of Mexico through the fall of 1929, and that seems altogether possible, we should have an explanation of the prevalent north winds over the far Western States during November.

9. Reference is made in 5 to the occurrence of cyclones over midocean and to their passing north and northeastward. It seems likely that west of the current of northerly winds prevailing in that month along our western coast, there must have been a countercurrent, a south wind, along which these midocean cyclones traveled to the Bering Sea. It is also possible that this south current accounted for the high temperatures in the interior of Alaska in that month.

10. The pressure rose decidedly in the early part of December over the Bering Sea and the western parts of Alaska, forming an area of high barometric pressure that extended thence eastward over Canada, and at the same time pressure gradually fell off our west coast and over that part of the ocean thence westward to and beyond the Hawaiian Islands. At the same time the northerly winds of the Western States gave way and became southerly and westerly. With this readjustment of the pressure situation over the northeast Pacific Ocean, the Bering Sea and the adjacent areas of the North American Continent, cyclones formed over the middle latitudes of the north Pacific Ocean and traveled toward the west coast, so that during the second week of December the dry season had ended generally in the far Western States except in southern California.[2]

The several distributions of barometric pressure with their associated wind systems, to be referred, of course, to the temperature distribution over large areas, are unquestionably what brought about the prolonged dry season in the far Western States in 1929.

It will be noted in paragraph 1 that the pressure distribution during the fall up to and including October of 1929 was such as to prevent the approach of cyclones to our coast south of latitude 50°; and that in numbered paragraph 2 reference is made to high barometric pressure and northerly winds along and off our western coast, which the cyclones over the ocean to the west could not penetrate. These cyclones were carried northward to the Bering Sea by a countercurrent, a south current, presumably of great width and considerable depth over midocean. It will be noted further that when the pressure rose in high latitudes, notably the Bering Sea and western Alaska, and decreased over the northeast Pacific Ocean (see par. 10) the dry-season soon came to an end, i. e., during the second week of December, except in Southern California.

# WEATHER AND COTTON YIELD IN TEXAS, 1899–1929, INCLUSIVE

551.5 : 633.51 (764)

By LAWRENCE H. DAINGERFIELD

[Weather Bureau Office, Houston, Tex.]

The tropical origin of cotton is easily demonstrated by its tolerance of heat and marked intolerance of cold. While it generally is safe to sow wheat when the average daily air temperature reaches 37° to 38° and oats at 42° to 44°, and plant corn at 55°, cottonseed should not go in the ground until the mean warmth reaches 62°, according to trustworthy authorities. Thus the planting period in Texas during a normal year may range from late February in the lower Rio Grande Valley until the middle of May in the northwestern cotton limits of the State. As a matter of fact there are wide variations from the normal planting dates due to early or backward seasons in consequence of favorable or unfavorable temperatures, and the presence or absence of moisture.

Roughly speaking, a month to six weeks may elapse in a normal season after the last killing frost of spring before the soil reaches the best temperature for proper germination; examination of frost tables will show this to be a fact. The warming-up process in spring and, conversely, the chilling in autumn are more rapid in the interior of the State than near the coast.

For the best growth of the plant, sustained high temperatures are favorable, both night and day, with a summer mean of not less than 77° F. The older varieties of cotton required a growing season of not less than 200 days for best results. New short-season or precocious varieties, with much less vegetable growth have shortened the season considerably, especially in the northwestern and western sections of the State. Cotton now normally begins to mature in from 100 to 135 days after planting, with a maturing period ranging from possibly only two weeks to as much as two months.

The first killing frost in autumn does not hold as much dread as formerly due to the introduction of early varieties, tendency to earlier planting, and for other reasons. Excessive rain during time of harvest, thus delaying pick-

[1] In the Pacific States north winds are dry and hot in summer and dry and cold in winter.—*E. H. B.*

[2] The dry season continued in southern California through December.

ing, beating out the open bolls, and staining the staple is, perhaps, a more detrimental factor than early frost danger.

Delayed planting due to late spring frosts, continued cold weather, excessive rain or drought is a greater deterrent to a full crop than ill-favored autumn conditions.

A poor "season" in the soil during the winter months is a marked factor for ill results, provided no balancing favorable weather follows during the season of (cotton) growth and maturity.

Wide variations in rainfall from month to month, especially during the growing season, are detrimental to yield. Excessive rain during the normal planting and cultivation season is rarely compensated for by sufficiently favorable weather during maturity and time of harvest to produce a normal crop.

Owing to the propagation and spread of the boll weevil since 1892, together with other insect pests to a lesser extent, new factors have arisen in recent years, materially complicating the weather and yield relationship. For instance in 1900, the second wettest year and the highest yield (219 pounds per acre) in this study (1899 to 1929, inclusive), the great cotton-producing counties of Williamson, Milam, Bell, Falls, McLennan, Limestone, Hill, Navarro, Ellis, Kaufman, Hunt, and Collin had not yet been invaded by the boll weevil. In 1919, the wettest year of record, and one of the five years of highest yield up to that time, weevil infestation had spread westward and northwestward to a line reaching from Wichita County to McCulloch, thence to Irion, thence to Valverde, or practically to its present limits, distinctly showing the reaction of weevil to rain, thus introducing a diametrically opposing factor, which was of minor consequence in 1900. Department of Agriculture data on reduction of cotton yield due to weevil damage amounted to 14 per cent in 1919, one of the three largest percentages of damage from like cause up to that time. Two years later, in 1921, weevil damage reached its peak in Texas, estimated at 33⅔ per cent, and cotton yield per acre dropped to its lowest ebb (98 pounds). The preceding winter had been unusually warm and fairly dry, followed by the wet months of April, June, and September, with alternating dry intervening months. The preceding winter weather was highly favorable for weevil during their dormant stage and large immergence in the spring. June, with the exception of 1899, was the wettest for that month in 31 years, seriously hindering proper cultivation.

January, 1922, February, March, and December, 1923, January, February, and December, 1924, and January, 1925, were all cold and well below their normals in temperature. It is interesting to note that they were followed by cotton seasons of constantly lessening weevil damage, reaching the lowest ebb in 1925 of only 2⅓ per cent or lowest since 1911. In 1925, the heat and drought of the following summer had a part in decreasing weevil activities; but this heat, at the same time, resulted disastrously for cotton, with the third lowest yield of record (113 pounds per acre). Following the warm winter of 1926-27, and mild, fairly moist summer, weevil emergence and damage again reached high marks, decreasing the yield by 20 per cent. While the cold December, 1927, and early January, 1928, somewhat lessened the weevil activities of the following summer, damage continued heavy (12 per cent), and was running high in 1929, with the second lowest yield per acre of record in prospect (108 pounds), due not only to abundance of insect pests, but to wide variations in monthly rain from the wettest of record in May to the general droughty conditions and the second driest August of the period considered.

An unfortunate and interesting tendency is known in connection with cotton insect and fungous pests, which comes under the general term, adaptation—to fit into changing environments. Overspecialization of a pest will ultimately make its destruction inevitable; the least adaptable will fall by the wayside while the more versatile pest persists.

To a certain extent the hosts, such as cotton, may be sufficiently adaptable to meet in part the onslaught of pests and grow stronger in specific adaptations. This fact is no doubt recognized in certain varieties, but is somewhat foreign to a study of weather and cotton yield, just as are the natural deterioration and erosion of the soil under constant cotton cropping, with resultant inevitable decline in yield. It is interesting to note in this connection, however, that a study of cotton yield in Texas during the last three decades shows the acre-yield for the whole period to have averaged 150 pounds, while the first decade shows an average of 169, the second decade of exactly 150, and the third or last decade shows only 131 pounds—a decline of 38 pounds per acre or 22½ per cent from the first decade, 1899 to 1908, inclusive.

It is quite obvious from this study that purely weather factors alone, which might have produced a fair or reasonably good crop in the early years, under happier conditions of better soil and fewer battling pests, may well produce an extremely short crop due to new factors or hazards at the present time.

High percentage of sunshine with resulting abundant warmth and low humidity are factors which tend to hold down weevil ravages and even destroy the weevil. Despite this very type of weather in the later summer weeks of this year, however, it is said that the overlapping of broods enabled the insects to be especially destructive in many places in Texas, more especially the south half. Perhaps this is an example of weevil adaptability.

Sunshine is usually in inverse ratio to rainfall or directly in proportion to the heat of summer.

TABLE 1.—*Weather and cotton yield in Texas*

| Year | Mean temperature: Departure from normal | | | | Killing frosts | | Mean precipitation: Departure from normal | | | | Boll Weevil infestation line | Per cent of damage | Cotton yield, pounds [1] | Departure from normal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Winter | Spring | Summer | Autumn | Spring | Autumn | Winter | Spring | Summer | Autumn | | | | Decade | 31 years |
| 1899 | − | + | + | + | L | E | − | − | + | + | S | ----- | 174 | +5 | +24 |
| 1900 | N | − | − | + | E | L | N | + | + | + | S | ----- | 219 | +50 | +69 |
| 1901 | + | − | + | + | E | L | − | − | − | − | A | ----- | 156 | −13 | +6 |
| 1902 | − | + | + | + | E | L | − | − | + | + | S | ----- | 144 | −25 | −6 |
| 1903 | − | − | − | − | L | L | + | − | + | − | A | ----- | 139 | −30 | −11 |
| 1904 | N | + | − | + | N | N | − | − | + | N | A | ----- | 179 | +10 | +29 |
| 1905 | − | N | N | + | N | E | N | + | + | + | A | ----- | 157 | −12 | +7 |
| 1906 | − | − | − | − | N | N | N | − | + | N | A | ----- | 214 | +45 | +64 |
| 1907 | + | − | N | N | E | L | − | + | − | + | S | ----- | 125 | −44 | −25 |
| 1908 | + | + | − | − | E | N | − | + | + | N | S | ----- | 187 | +18 | +37 |
| 1909 | + | N | + | + | L | N | − | − | − | − | S | 12 | 119 | −31 | −31 |
| 1910 | − | N | + | + | N | N | − | − | − | − | S | 7 | 145 | −5 | −5 |
| 1911 | + | + | + | N | E | E | − | N | − | − | R | 1 | 180 | +30 | +30 |
| 1912 | − | − | + | N | N | L | + | − | − | − | A | 3 | 197 | +47 | +47 |
| 1913 | − | − | N | − | N | E | N | − | − | + | R | 7 | 144 | −6 | −6 |
| 1914 | N | − | + | + | L | N | N | + | + | + | A | 8 | 177 | +27 | +27 |
| 1915 | − | − | − | + | L | L | N | + | N | − | A | 16 | 140 | −10 | −10 |
| 1916 | + | + | + | N | N | N | − | − | + | − | S | 18½ | 150 | 0 | 0 |
| 1917 | + | − | + | − | L | E | − | − | − | − | S | 7 | 135 | −15 | −15 |
| 1918 | − | + | + | − | E | L | − | − | − | + | R | 4½ | 115 | −35 | −35 |
| 1919 | − | − | − | N | E | N | + | + | + | + | S | 14 | 136 | −3 | −14 |
| 1920 | + | N | − | + | L | L | + | − | + | + | A | 20 | 167 | +28 | +17 |
| 1921 | + | + | N | + | L | L | − | N | − | − | S | 33⅔ | 98 | −41 | −52 |
| 1922 | + | + | + | + | N | L | N | + | − | − | ---- | 16 | 126 | −13 | −24 |
| 1923 | + | N | + | − | N | L | + | + | − | + | ---- | 10 | 143 | +6 | −7 |
| 1924 | − | − | + | + | L | L | + | + | − | − | ---- | 7⅓ | 136 | −3 | −14 |
| 1925 | − | + | + | − | E | E | − | − | − | + | ---- | 2⅓ | 113 | −26 | −37 |
| 1926 | − | − | N | + | N | L | − | + | N | N | ---- | 11 | 147 | +8 | −3 |
| 1927 | + | + | N | + | L | E | + | − | + | N | ---- | 20 | 129 | −10 | −21 |
| 1928 | N | N | + | − | N | N | + | − | N | N | ---- | 12 | 139 | 0 | −11 |
| 1929 | − | + | + | − | X | X | + | + | − | + | ---- | ----- | 108 | −31 | −42 |

(+) Above normal. (−) Below normal. (N) Normal. (E) Early. (L) Late. (A) Advanced. (R) Retreated. (S) Stationary.

[1] Mean yield: 1899 to 1908, inclusive, 169 pounds; 1909 to 1918, 150 pounds; 1919 to 1929, inclusive, 131 pounds. Mean of 31 years, 150 pounds. No attempt made in above table to state amount of departures in exact amounts for temperature and precipitation.

### CONCLUSIONS

Good winter and early spring subsoil moisture indicates a good cotton season; but unfavorable condition during growing season, such as violent monthly rainfall change from wet to dry, continuous heavy to excessive rains, with resulting poor cultivation and heavy weevil infestation, may easily offset the early advantage. A cold winter tends to destroy the hibernating insects and cut down the spring emergence; this favorable cotton factor, however, may be offset by late planting and a moist cool growing season, favoring the rapid multiplication of pests at a time when they will do the greatest harm to the delayed crop. On the contrary the disadvantages of a dry, abnormally warm winter or a late cold or extremely wet spring may be largely compensated for by later exceptionally favorable weather conditions.

Other things being equal, the ideal year for cotton would be one in which there was good soil-moisture storage during the preceding winter, which should be sufficiently cold to destroy the hibernating pests; followed by an early spring of moderate rainfall, promoting planting and cultivation of crop; a moderately dry, hot summer, with abundant sunshine, but not really droughty and not subject to sharp reversals in rainfall or temperature, thus favoring care and growth of crop and holding down weevil (this condition would favor certain other insects, however, of less serious nature). Finally, a fairly dry, bright autumn and late frost, to remove all of the cotton from the fields without deterioration or loss.

The vast area of Texas greatly complicates the study of weather and cotton yields. Within the State's borders, we have the semitropical climate of the lower Rio Grande Valley and the rigorous Temperature Zone climate of the Panhandle; the 50-inch annual rainfall of the lower Neches and Sabine Rivers in the southeast to the 10-inch rainfall of the extreme west; the long, flat reaches of the Coastal Plain to the high cap-rocked Llano Estacado and the rugged Trans-Pecos region.

Through the wide reaches of the State from the marine climate of the coast to the continental climate of the interior, there seems to be a persistent tendency toward zonal rainfall, i. e., for heavy precipitation to occur along the coast or paralleling it, even for hundreds of miles inland, materially affecting the average moisture over the State, and yet remaining more or less localized. While this fact is known, in a general review like this present study it is impracticable to enter into a discussion of these more specialized conditions, which often complicates the whole study, and deserves and should receive a careful analysis as to causes, locations, and frequency.

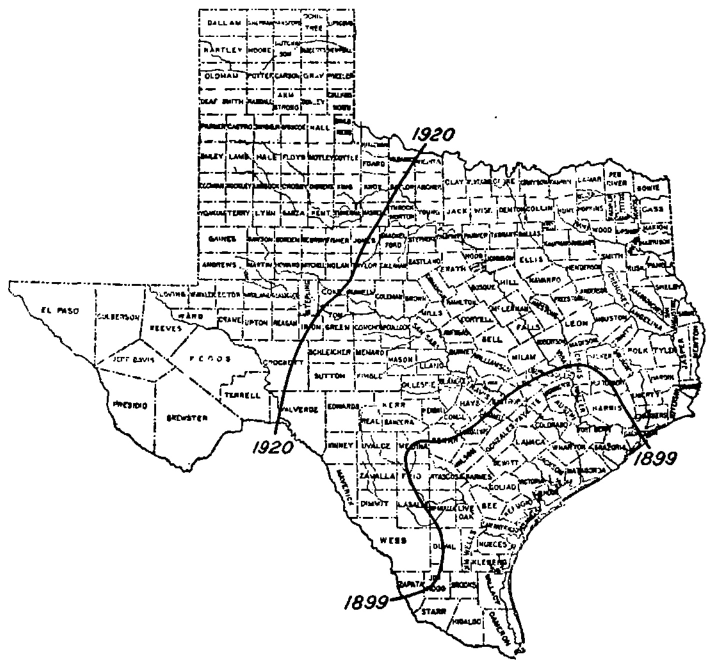


FIGURE 1.—Spread of Mexican cotton-boll weevil 1899–1920. Not much advance since 1920

For further study on weather and agriculture in general see Department of Agriculture Yearbook, 1924, pages 457 to 558, inclusive, by A. J. Henry, J. B. Kincer, H. C. Frankenfield, and W. R. Gregg, of the Weather Bureau, B. B. Smith, Bureau of Agricultural Economics, and E. N. Munns, Forest Service; Climatic Factors in the Agriculture of Louisiana and Southern Mississippi by W. F. McDonald, Weather Bureau, New Orleans.

## RELATIONS BETWEEN SUMMERS IN INDIA AND WINTERS IN CANADA[1]

551.58 (71) (54)

By FRED GROISSMAYR

(Passau, Germany, September, 1929)

The weather elements of Argentina, Egypt, and especially East India are of enormous influence upon the following Canadian winters, nine months to three months later, as the correlation table distinctly shows:

$\Delta t$ XII–II Winnipeg, Manitoba, 1877–1878 to 1920–1921

Correlations with preceding elements:

| Argentina | Egypt | India |
|---|---|---|
| Goya: $\Delta t$ I–VII: +0.55<br>$\Delta N$ IV: +0.51 | Nile VII–X at Assuan −0.50 | $\Delta p$ I–X Nagpur +0.74<br>$\Delta t$ VII–X India +0.73<br>$\Delta N$ I–X India −0.56 |

$t$ = temperature, $p$ = pressure, $N$ = precipitation, I–XII = months, $\Delta t$ VII–X India = (Cochin + Madras)/2; $\Delta N$ I–X India = (Jaipur + Nagpur + Allahabad + Masulipatam + Waltair)/5. Uniting Goya January–July temperatures and the three Indian weather elements, I have obtained the following:

Winter temperature forecasting formula for Winnipeg: $\Delta t$ XII–II Winnipeg = 0.13 $\Delta p$ I–X Nagpur + 2.6 $\Delta t$ VII–X India − 0.13 $\Delta N$ I–X India + 0.85 $\Delta t$ I–VII Goya.

These four elements give a total correlation of, $r = 0.81$ with $\Delta t$ XII–II Winnipeg; the computed values (de-

[1] Much of the preliminary work on which this note is based is described in a previous paper published in the May, 1929, issue of *Meteorologische Zeitschrift* under the title "Der Einfluss der Wetterfaktoren Indiens auf den Folgewinter Kanadas." See abstract and excerpts on following pages.—*Editor.*